16.422
Human Supervisory Control

Function Allocation and Task Analysis
Human Systems Engineering

16.422

Planning → Analysis → Detail Design → Test & Evaluation
Functions & Tasks

16.422

Planning

Mission & Scenario Analysis

Function Analysis

Function Allocation

Task Analysis

System Design

Analysis

Design

Test & Evaluation
### Fitts’ List

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Machine</th>
<th>Human</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>Superior</td>
<td>Comparatively slow</td>
</tr>
<tr>
<td></td>
<td>Superior in level in consistency</td>
<td>Comparatively weak</td>
</tr>
<tr>
<td>Power Output</td>
<td>Ideal for consistent, repetitive action</td>
<td>Unreliable, learning &amp; fatigue a factor</td>
</tr>
<tr>
<td>Consistency</td>
<td>Multi-channel</td>
<td>Primarily single channel</td>
</tr>
<tr>
<td>Information Capacity</td>
<td>Ideal for literal reproduction, access restricted and formal</td>
<td>Better for principles &amp; strategies, access versatile &amp; innovative</td>
</tr>
<tr>
<td>Memory</td>
<td>Deductive, tedious to program, fast &amp; accurate, poor error correction</td>
<td>Inductive, easier to program, slow, accurate, good error correction</td>
</tr>
<tr>
<td>Reasoning Computation</td>
<td>Good at quantitative assessment, poor at pattern recognition</td>
<td>Wide ranges, multi-function, judgment</td>
</tr>
<tr>
<td>Sensing</td>
<td>Copes with variation poorly, susceptible to noise</td>
<td>Copes with variation better, susceptible to noise</td>
</tr>
<tr>
<td>Perceiving</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Hollnagel, 2000*

**Inductive and deductive.** Induction is usually described as moving from the specific to the general, while deduction begins with the general and ends with the specific; arguments based on experience or observation are best expressed inductively, while arguments based on laws, rules, or other widely accepted principles are best expressed deductively.
Some problems with Fitts…

- Tasks/functions defined in machine terms, not human-oriented
  - Introduces a bias
  - “Laws of human behavior”
- Environmental/ecologic context
- Learning, fatigue, stress, anxiety generally not incorporated into design picture
- Task division vs. task complement
- Static vs. dynamic allocation
  - Adaptive allocation/automation
  - Function allocation is not binary

- Bandwidth
- Trust
- Machine/computer metaphors
Designing automation to support information processing

*Parasuraman, Sheridan, Wickens, 2000*
A Model of Types and Levels of Automation*

- What should be automated?
- Identify types of automation
  - Information Acquisition
  - Information Analysis
  - Decision & Action Selection
  - Action Implementation
- Identify levels of automation
  - Low (manual)
  - High (full automation)
- Apply primary evaluative criteria:
  - Human Performance Consequences
    - Mental workload
    - Situation awareness
    - Complacency
    - Skill degradation
- Initial types & levels of automation
- Apply secondary evaluative criteria:
  - Automation reliability
  - Costs of action outcomes
- Final types & levels of automation

*Parasuraman, Sheridan, Wickens, 2000
### Sheridan and Verplank’s 10 Levels of Automation of Decision and Action Selection

<table>
<thead>
<tr>
<th>Automation Level</th>
<th>Automation Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The computer offers no assistance: human must take all decision and actions.</td>
</tr>
<tr>
<td>2</td>
<td>The computer offers a complete set of decision/action alternatives, or narrows the selection down to a few, or</td>
</tr>
<tr>
<td>3</td>
<td>suggests one alternative, and executes that suggestion if the human approves, or</td>
</tr>
<tr>
<td>4</td>
<td>executes automatically, then necessarily informs humans, and informs the human only if asked, or</td>
</tr>
<tr>
<td>5</td>
<td>allows the human a restricted time to veto before automatic execution, or</td>
</tr>
<tr>
<td>6</td>
<td>informs the human only if it, the computer, decides to.</td>
</tr>
<tr>
<td>7</td>
<td>The computer decides everything and acts autonomously, ignoring the human.</td>
</tr>
</tbody>
</table>
What should be automated?

Identify types of automation

Information Acquisition
Information Analysis
Decision & Action Selection
Action Implementation

Identify levels of automation

Low (manual)  High (full automation)

Apply primary evaluative criteria:
Human Performance Consequences
  • Mental workload
  • Situation awareness
  • Complacency
  • Skill degradation

Initial types & levels of automation

Apply secondary evaluative criteria:
  • Automation reliability
  • Costs of action outcomes

Final types & levels of automation

*A Model of Types and Levels of Automation*

*Parasuraman, Sheridan, Wickens, 2000*
Function Allocation Criteria

1: No difference in the relative capabilities of human & machine.
4: Machine performance is so poor that the functions should be allocated to humans.
5: Human performance is so poor that the functions should be allocated to machine.
6: Unacceptable performance by both human and machine.

Three function allocation criteria:
- Balance of value
- Utilitarian & cost-based allocation
- Allocation for affective or cognitive support.
Functions & Tasks

Planning

Mission & Scenario Analysis

Analysis

Function Analysis

Function Allocation

Task Analysis

Design

System Design

Test & Evaluation
Task Analysis

• Determining what an operator must accomplish to meet a mission goal
  – Interactions both on a local and system level are critical
  – Will contain actions and/or cognitive processes

• Flow process charts, operational sequence diagrams, critical task analysis
  – Attempt to understand how a particular task could exceed human limitations, both physical and cognitive

• Cognitive task analysis
  – Not the only system analytic method but a critical one
  – Shift away from system control to systems management.

Supervisory control becoming more about cognitive tasking than manual tasking, especially with increasing automation
Cognitive Task Analysis (CTA)

- Goal: To analyze and represent the knowledge and cognitive activities needed in complex work domains
- CTA is generally a descriptive modeling technique of workers’ knowledge and cognition
  - As opposed to Computational Cognitive Models (CCM)
  - Knowledge Elicitation techniques provide input to CTA and CCM
    - Experts vs. Novices
- Evolutionary systems vs. revolutionary systems
- Background Research
  - Standards, procedures, manuals, organizational charts
- Field Studies
  - In both real environments and high fidelity simulations
- Questionnaires/Surveys

http://www.ul.ie/~infopolis/methods/incident.html
CTA, Cont.

• Interviews
  – Individuals vs. focus groups
  – Critical Incident Technique/Critical Decision Method

• Observations
  – PARI Method (Precursor (reason for action), Action, Result, Interpretation (of result))
  – Verbal protocols

• Design Reviews
  – Usability, Expert, Heuristic

• Problems with CTA
  – Labor intensive
  – Generate much data that is difficult to analyze
  – Gap between CTA and design
  – Opportunistic
CTA: A Bootstrapping Process

- critical decision method in which participants are asked to describe a specific decision-making incident in detail and then to respond to probes seeking elaboration of important aspects of the decision sequences.
- Semantic mapping (a.k.a., mind-mapping, idea mapping, word webbing, etc.) is a term which describes a variety of strategies designed to show how key words or concepts are related to one another through graphic representations. Mapping is an effective technique for teaching vocabulary and textual patterns of organization; and it is also effective for improving note taking and creative thinking skills.
# Functional Means/Ends Analysis

<table>
<thead>
<tr>
<th>Abstraction (Means/ends)</th>
<th>Decomposition (Whole/Part)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total System</td>
</tr>
<tr>
<td>Functional Purpose</td>
<td></td>
</tr>
<tr>
<td>Abstract Function</td>
<td></td>
</tr>
<tr>
<td>Generalized Function</td>
<td></td>
</tr>
<tr>
<td>Physical Function</td>
<td></td>
</tr>
<tr>
<td>Physical Form</td>
<td></td>
</tr>
</tbody>
</table>

- **Abstraction (Means/ends):**
  - Functional Purpose
  - Abstract Function
  - Generalized Function
  - Physical Function
  - Physical Form

- **Decomposition (Whole/Part):**
  - Total System
  - Subsystems
  - Subassembly
  - Component
CTA: A Bootstrapping Process

Understanding the way people operate in their world

- Goal: Understand/model expertise, knowledge, strategies, and error
- Techniques: Semantic Mapping, Ethnographic/observational investigations, Critical Incident Technique, Critical Decision Method, Structured Interview Techniques

Discovering support for how people will operate in their world

- Goal: Discovery of unsupported expertise, knowledge, and strategies
- Techniques: Storyboard walkthroughs, Participatory design, Wizard-of-Oz technique, High-fidelity simulations

Understanding the way the world works

- Goal: Understand/model complexities, demands, variability, and complicating factors
- Techniques: Functional/means-ends analysis, Ethnographic/observational investigations, Functional Task and Workflow Modeling, Structured Interview Techniques

Discovering how to support the way the world will work

- Goal: Discovery of unsupported complexities, demands, variability, and complicating factors
- Techniques: Scenario generation based on:
  - Textbook cases
  - Complicating factors
  - Cascading effects
  - Exceptions

Adapted from Carnegie Group, Inc.

WoZ: http://www.dcs.napier.ac.uk/Usability/WizardOfOz.html
Work Analysis v. Task Analysis

- Descriptive v. Normative v. Prescriptive
- Ecological focus
  - Constraints v. instructions
  - Map v. directions
- Not a mutually exclusive set

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Task Analysis</th>
<th>Work Domain Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental Economy</td>
<td>Efficient</td>
<td>Effortful</td>
</tr>
<tr>
<td>Unforeseen Circumstances</td>
<td>Brittle</td>
<td>Flexible</td>
</tr>
<tr>
<td>Scope of Applicability</td>
<td>Narrow</td>
<td>Broad</td>
</tr>
</tbody>
</table>

Normative analysis focuses on "how decision makers should ideally perform" an activity. Bell et al. (1988) have claimed that "normative theory has something to do with how idealized, rational, super-intelligent people should think and should act." Normative analysis is often contrasted with prescriptive analysis, which is usually said to be geared toward examining what real people ought to do given their real-world constraints and cognitive limitations (or how decision aids might aid real decision makers).
Resources

• A Survey of Cognitive Engineering Methods and Uses
  – http://mentalmodels.mitre.org/cog_eng/index.htm

• ONR/Aptima Cognitive Task Analysis website
  – http://www.ctaresource.com/